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(71) Applicant (for all designated States except US): INSTI-
TUTT FOR ENERGITEKNIKK [NO/NO]; Boks 40,
N-2007 Kjeller (NO).

(72) Inventor; and

(75) Inventor/Applicant (for US only) : VIDEM, Ketil [NO/
NO]; Blåveissien 7, N-2007 Kjeller (NO).(74) Agent: LEVKOWETZ, Henrik; Postboks 2584 Solli, N-
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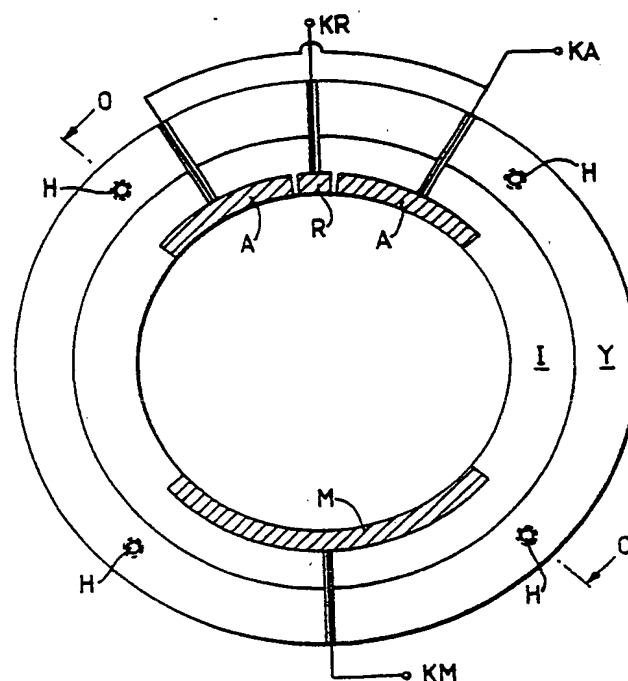
With international search report.

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(54) Title: ELECTRODE SYSTEM FOR THE MEASUREMENT OF CORROSION RATE

(57) Abstract

An electrode system (E) for the measurement of corrosion rate of metal subjected to corrosion in watery medium comprises two electrodes (A+R, M) of the respective metal, which are disposed in spaced relationship to be submerged into the watery medium and convey electric current through the same. The metal electrodes (A+R, M) are disposed on the interior surface of a ring (I) of electrically insulating material with their active electrode surfaces spaced apart and preferably flush with and having the same curvature as the interior surface of the ring (I). An outer annular flange (Y) of high strength material is mounted around and rigidly secured to the inner ring (I) of insulating material. The outer annular flange and the inner ring as well as the metal electrodes are then configured and dimensioned to fit in and be liquid-tight maintained between flanges on pipe sections (S1, S2) which are joined together to form a pipeline for the through-flow of said watery medium. At least one of the electrodes (A+R) is preferably subdivided into a working electrode and a reference electrode (R), which are spaced far less apart than said distance between the two electrode surfaces. If the voltage drop between the reference electrode and the working electrode is measured when a prescribed current is flowing between the working electrode and the counter electrode in the watery medium, the polarization resistance of the corrosive reaction on the working electrode may be determined with high accuracy.



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Electrode System for the Measurement of Corrosion Rate.

The present invention is related to an electrode system for the measurement of corrosion rate of metal in watery medium.

Many different methods are developed for the measurement of corrosion rate, e.g. as disclosed in a paper presented at BSE/NACE "Middle East Corrosion Conference", and having the title "The Importance of Corrosion Monitoring in Oilfield Systems". Here it is also indicated that the corrosion rate of metal which is submerged in electrolytically conducting watery environment, may be determined by applying a weak potential in addition to the free corrosion potential between mutually separated electrodes in said environment, upon which current and voltage between the electrodes are measured and the corresponding equivalent linear polarization resistance R_p between the electrodes deduced. The corrosion rate I_c is then determined by means of the formula:

$$I_c = \frac{C}{R_p}$$

The constant C must then be settled by other measurements, and the formula is only valid for small values of the applied current and voltage. This formula also presupposes that the current between the electrodes is primarily limited by the corrosion reactions on the two electrodes at the applied voltage. If, however, the electrolyte resistance in itself is a substantial part of the resistance R_p included in the above formula, this formula will indicate a too low corrosion rate and may imply an expectation of a substantially lower corrosion rate than the one actually appearing, which in many cases may be risky.

Probes for the measurement of such linear polarization resistance are usually very simple, and e.g. consists of two steel pieces which are spaced about 1 cm apart. Devices of this type are, however, not well suited for continuous

monitoring of corrosion conditions in practice, e.g. in a pipeline. It is therefore an object of the present invention to provide an electrode system which is particularly suited for such monitoring and may readily be fitted into even existing liquid carrying structures.

Thus, the invention relates to an electrode system for the measurement of corrosion rate of metal subjected to corrosion in watery medium, the electrode system comprising two electrodes of the respective metal disposed in spaced relationship to be submerged into the watery medium and convey electric current through the same.

On this background of known art the characteristic features of the electrode system according to the invention are that the metal electrodes are disposed on the interior surface of a ring of electrically insulating material and with their active electrode surfaces mutually spaced, an outer annular flange of high strength material being mounted around and rigidly secured to the inner ring of insulating material, and the outer annular flange and the inner ring as well as the metal electrodes being configured and dimensioned to be adapted and liquid-tight maintained between flanges on pipe sections which are joined together to form a pipeline for the through-flow of said watery medium.

With such an embodiment according to the invention a geometric configuration is achieved, which in simple manner and without special measures allows a location of the electrode system between the flanges of pipe sections interconnected into a pipeline. the active electrode surfaces are here preferably disposed flush with and having the same curvature as the interior surface of the ring of insulating material, the interior diameter of the ring being preferably substantially equal to the interior diameter of the adapted pipe sections.

In a highly preferred embodiment at least one of the

electrodes is subdivided into a reference electrode and a working electrode being spaced far less apart than the mutual distance between said electrode surfaces.

The working electrode is in turn preferably divided into two approximately equal parts, the reference electrode being located with small clearance between said parts.

Further, current conductors which are electrically connected with the electrodes, are passed through radial holes in the ring of insulating material and the annular flange onto terminals exterior to the electrode systems.

Measuring current is then caused to flow through the working electrode and the other electrode (the counter electrode), while measuring voltage drop between the reference electrode and the working electrode. The ratio of this voltage drop and the measuring current represents the equivalent polarization resistance of the corrosion process generated by the measuring current on the working electrode. As the voltage drop is measured across the small interspace between the working and reference electrodes, the resistance of the electrolyte itself does not contribute significantly to this voltage drop, which therefore essentially is a measure of the voltage difference between freely corroding metal and metal subjected to corrosion with current load.

The corresponding voltage drop may possibly be achieved in similar manner at the other electrode, which then also must be subdivided into a working electrode and a reference electrode, or it may be deduced at the same electrode with opposite current flow direction. The sum of the two voltage drops and the current between the active electrode surfaces are then employed for calculating the total polarization resistance R_p which is included in the above formula for the corrosion rate I_c .

The invention is now explained in more detail by means of an exemplary embodiment with reference to the accompanying drawings, whereon:

Fig. 1 shows a view in axial direction of an embodiment of the electrode system according to the invention, and
Fig. 2 shows this electrode system in section along the line O-O in fig. 1 and in operative position clamped between end flanges of two interconnected pipe sections.

Fig. 1 shows a readily mounted electrode system according to the present invention and viewed in the axial direction. This system comprises two electrodes mounted directly opposite each other on the interior side of the inner ring I of insulating material. The electrodes and the insulating ring are supported by an outer annular flange Y of steel, placed around the inner ring and rigidly secured to the same.

One of the electrodes is subdivided into a working electrode A and a reference electrode R, the working electrode being in turn divided in two parts disposed symmetrically with respect to the reference electrode with a small clearance on opposite sides of the same. These two parts are interconnected by means of insulated leads, which are passed through narrow radial bores in the inner insulation ring I and the outer steel ring Y. This interconnection is linked to an exterior terminal KA for connection to one pole of a voltage source. The other pole of the voltage source (not shown) is then connected to an exterior terminal KM, which by means of an insulated lead through the inner and outer ring I, Y is linked to the other electrode M, which usually is termed counter electrode.

The reference electrode R is connected with its associated measuring terminal through an insulated lead, which in the same manner as the other leads is passed through radial holes in the inner and outer ring. These radial holes may be sealed by means of a suitable sealing paste around the through-

passed leads.

The measuring terminal KR receives no voltage, but is used for measuring the voltage drop between the reference electrode R and the working electrode A when a measuring current is flowing between the counter electrode M and the working electrode A, caused by a suitable weak potential applied between the latter electrodes by means of a voltage source connected between the terminals KA and KM.

The measured voltage between the reference electrode R and the working electrode A represents, due to the very small distance between these electrodes, essentially the voltage drop across the corrosion process produced by the measuring current on the surface of the working electrode, and with known values of measuring current and voltage drop the polarization resistance may be determined, and thereby also the corrosion rate, by means of the initially presented formula.

With measurements demanding high precision when determining the voltage drop across the corrosion process on the working electrode, a correction may be made as to the voltage drop in the electrolyte. This voltage drop follows Ohm's Law and is accordingly proportional to the current, the specific resistance of the electrolyte and a geometric factor (the cell constant). This geometric factor is the same for all electrode systems having the same dimensions and configuration and may be determined e.g. by means of alternating current measurements. Such a correction as to the voltage drop in the electrolyte requires that the specific resistance of the watery medium is known, which however, may be measured separately by means of ordinary known measuring techniques.

The electrode system according to the invention is particularly configured and dimensioned for readily insertion in a pipeline conveying a watery solution of corrosive substances.

This is achieved by clamping the electrode system E between the flanges of two adjoining pipe sections S1, S2 of the pipeline, as schematically shown in fig. 2. For this purpose the outer ring Y is provided with boltholes H for the insertion of clamping bolts (not shown) between the flanges of the adjoining pipe sections.

The electrodes A, R and M on the inside of the insulation ring I have here preferably the same curvature as the interior surface of the ring and are disposed flush with this surface, which in turn suitably has the same interior diameter as the pipe sections S1 and S2, in order that no additional flow resistance or whirlforming protrusion is introduced in the pipeline.

Due to the circumstance that the voltage drop in the electrolyte only to a small degree is included in the measured voltage and if necessary may be calculated, the electrode system according to the invention is capable of providing more accurate measurements of the ratio of current and voltage than has been possible up to now. This allows use of the electrode system also for other methods of determining the corrosion rate than the above indicated deduction of linear polarization resistance. Measurements of the ratio of current and voltage with high accuracy allow determining the constant C in the formula on page 1 directly on the basis of prevailing conditions, rather than being dependent on more or less reliable values to be found in the literature or from personal experience.

Such a determination of the constant C is particularly important when corrosion inhibitors are used, which may effect a substantial variation of this "constant".

The electrode system of the present invention is also well suited for corrosion determination by alternating current measurements and for use with the so-called RC-method, which has been developed by Institutt for Energiteknikk.

CLAIMS.

1. Electrode system for the measurement of corrosion rate of metal subjected to corrosion in watery medium, the electrode system (E) comprising two electrodes (A+R, M) of the respective metal disposed in spaced relationship to be submerged into the watery medium and convey electric current through the same,

c h a r a c t e r i z e d i n that the metal electrodes (A+R, M) are disposed on the interior surface of a ring (I) of electrically insulating material and with their active electrode surfaces mutually spaced, an outer annular flange (Y) of high strength material being mounted around and rigidly secured to the inner ring (I) of insulating material, and the outer annular flange and the inner ring as well as the metal electrodes being configured and dimensioned to be adapted and liquid-tight maintained between flanges on pipe sections (S1, S2) which are joined together to form a pipeline for the through-flow of said watery medium.

2. Electrode system as claimed in claim 1,

c h a r a c t e r i z e d i n that the active electrode surfaces are disposed in mutually facing relationship flush with and having the same curvature as the interior surface of the ring (I) of insulating material, the interior diameter of the ring being preferably substantially equal to the interior diameter of the adjoined pipe sections.

3. Electrode system as claimed in claim 1 or 2,

c h a r a c t e r i z e d i n that at least one of the electrodes is subdivided into a reference electrode (R) and a working electrode (A) being spaced far less apart than the mutual distance between said electrode surfaces.

4. Electrode system as claimed in claim 3, characterized in that the reference electrode (R) has a substantially smaller active surface than the working electrode (A).

5. Electrode system as claimed in claim 3 or 4, characterized in that the interspace between the reference electrode and the working electrode is substantially smaller than the active electrode surface of each of the electrodes.

6. Electrode system as claimed in claims 3 - 5, characterized in that the working electrode is divided into two approximately equal parts, the reference electrode being located with small clearance between said parts.

7. Electrode system as claimed in claims 1 - 5, characterized in that current conductors which are electrically connected with the electrodes, are passed through radial holes in the ring of insulating material and the annular flange onto terminals exterior to the electrode systems.

Fig.1.

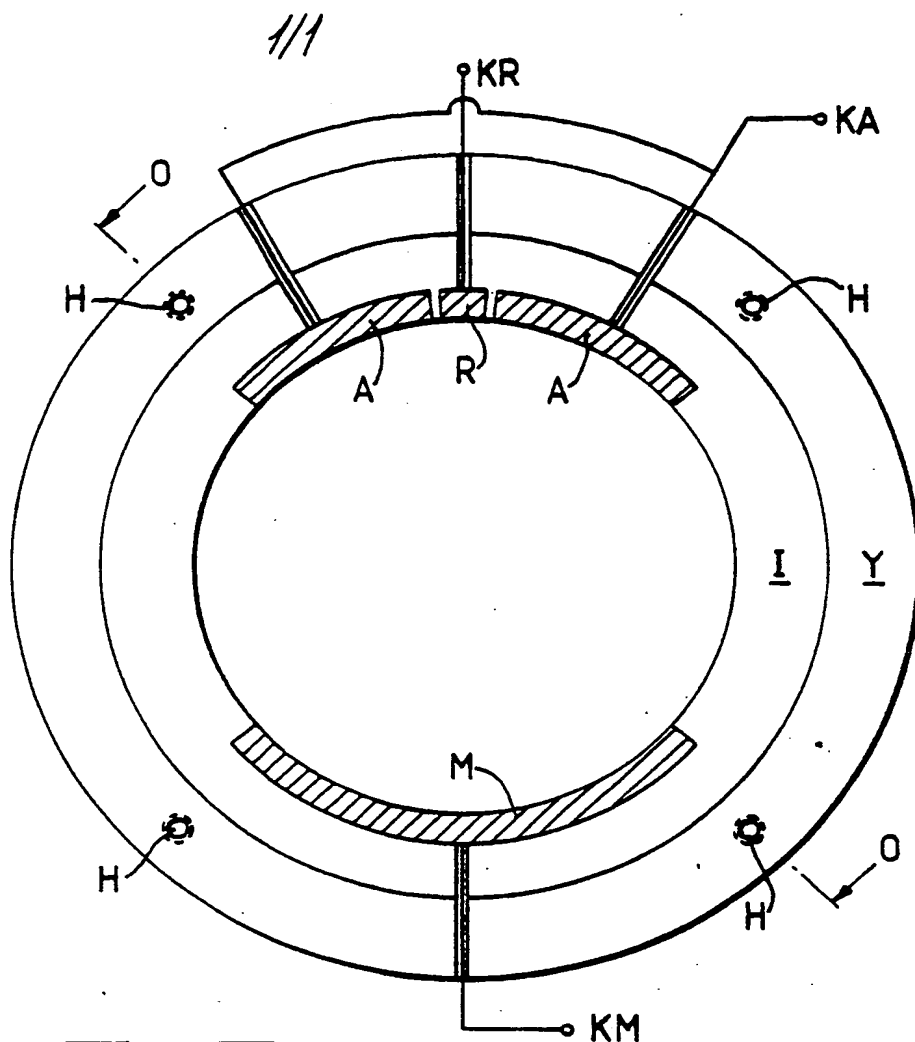
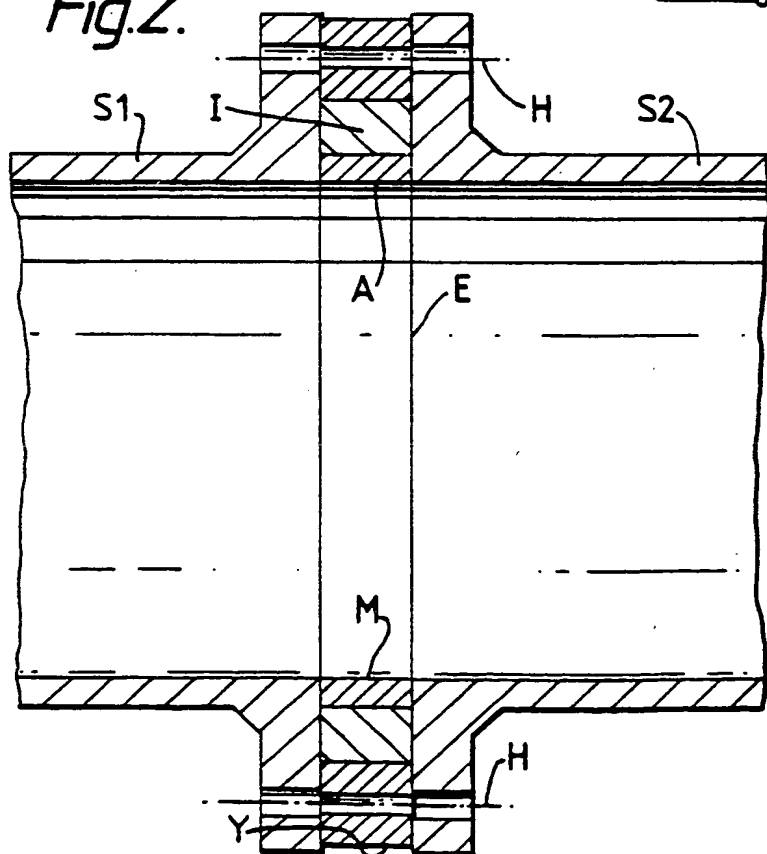


Fig.2.



INTERNATIONAL SEARCH ORT

International Application No PCT/NO84/00048

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶ According to International Patent Classification (IPC) or to both National Classification and IPC ⁴ <div style="text-align: center; font-size: 1.2em;">G 01 N 17/00, 27/46</div>																	
II. FIELDS SEARCHED <div style="text-align: center; font-size: 0.8em;">Minimum Documentation Searched ⁷</div> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 25%; padding: 5px; vertical-align: top;"> Classification System IPC 4 US C1 </td> <td style="padding: 5px;"> Classification Symbols G 01 N 17/00, 27/30, 46 73:86; 324:65, 71 </td> </tr> </table> <div style="text-align: center; font-size: 0.8em; margin-top: 5px;"> Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸ </div> <div style="text-align: center; padding: 10px 0;"> SE, NO, DK, FI classes as above </div>			Classification System IPC 4 US C1	Classification Symbols G 01 N 17/00, 27/30, 46 73:86; 324:65, 71													
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III. DOCUMENTS CONSIDERED TO BE RELEVANT ⁹ <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 10%; padding: 5px;">Category ¹⁰</th> <th style="width: 70%; padding: 5px;">Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²</th> <th style="width: 20%; padding: 5px;">Relevant to Claim No. ¹³</th> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">X</td> <td style="padding: 5px;"> EP, A1, 39 750 (IMPERIAL CHEMICAL INDUSTRIES LIMITED) 18 November 1981 & US, 4338097 </td> <td style="text-align: center; vertical-align: top; padding: 5px;">1-2</td> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">X</td> <td style="padding: 5px;"> EP, A1, 52 388 (CISE-CENTRO INFORMAZIONI STUDI ESPERIENZE S P A) 26 May 1982 & US, 4426618 </td> <td style="text-align: center; vertical-align: top; padding: 5px;">1-2</td> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">X</td> <td style="padding: 5px;"> SE, B, 335 435 (INTERNATIONAL BUSINESS MACHINES CORPORATION) 24 May 1971 </td> <td style="text-align: center; vertical-align: top; padding: 5px;">1-2</td> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">X</td> <td style="padding: 5px;"> DE, A, 2 711 529 (THE FOXBORO CO) 22 September 1977 & US, 4033830 FR, 2344835 GB, 1524652 AU, 22490/77 JP, 52112390 CA, 10703388 SE, 7703026 <div style="text-align: right; font-size: 0.8em;">.../...</div> </td> <td style="text-align: center; vertical-align: top; padding: 5px;">1-2</td> </tr> </table>			Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³	X	EP, A1, 39 750 (IMPERIAL CHEMICAL INDUSTRIES LIMITED) 18 November 1981 & US, 4338097	1-2	X	EP, A1, 52 388 (CISE-CENTRO INFORMAZIONI STUDI ESPERIENZE S P A) 26 May 1982 & US, 4426618	1-2	X	SE, B, 335 435 (INTERNATIONAL BUSINESS MACHINES CORPORATION) 24 May 1971	1-2	X	DE, A, 2 711 529 (THE FOXBORO CO) 22 September 1977 & US, 4033830 FR, 2344835 GB, 1524652 AU, 22490/77 JP, 52112390 CA, 10703388 SE, 7703026 <div style="text-align: right; font-size: 0.8em;">.../...</div>	1-2
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<div style="display: flex; justify-content: space-between; font-size: 0.8em;"> <div style="width: 45%;"> <p>¹⁰ Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 45%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&" document member of the same patent family</p> </div> </div>																	
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III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	GB, A, 2 006 437 (TOKYO SHIBAURA DENKI KABUSHIKI KAISHA) 2 May 1979	1-7
A	GB, A, 1 150 416 (NATIONAL RESEARCH DEVELOPMENT CORP) 30 April 1969	1-7
A	EP, A1, 100 814 (PETROLITE CORPORATION) 22 February 1984	1-7

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